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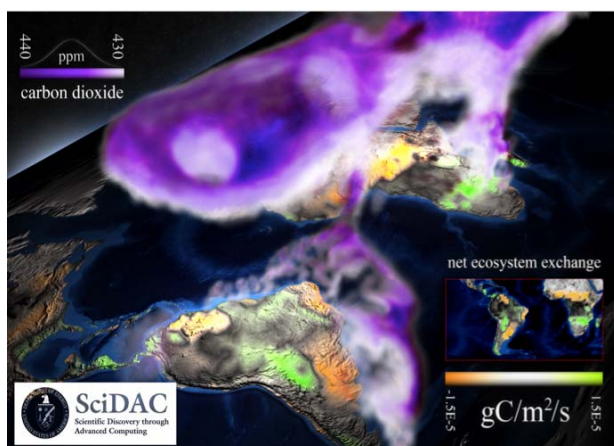
## Earth System Grid Support for High Resolution Earth System Models

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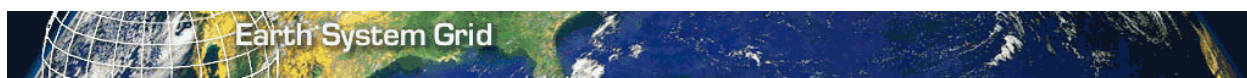
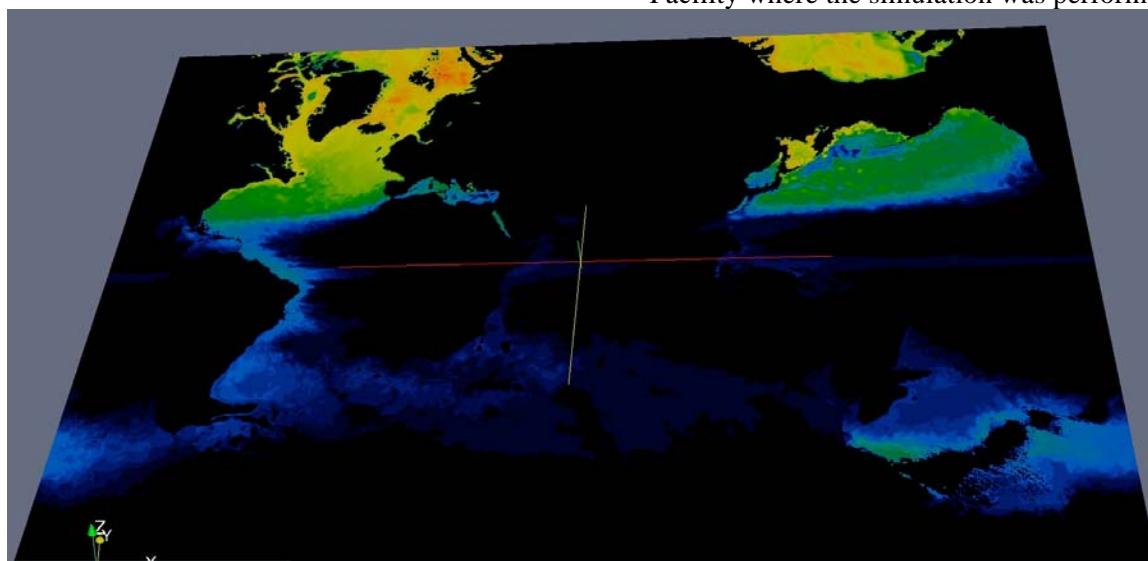
### Summary

The Earth System Grid (ESG) project has played an integral role in making climate model simulation data available to the climate science community. Current and future generations of climate models are both increasing spatial resolution and adding biogeochemical cycles. ESG has played an important role in evaluating new land surface models that include the full carbon cycle. ESG researchers are also developing, prototyping and incorporating new tools for remote parallel visualization and analysis. Both of these efforts directly support SciDAC climate science projects as well as the Computation Climate End Station under which many of these simulations are undertaken.



**Figure 1. (left)** The CO<sub>2</sub> tracer originating from the land surface is shown as a violet cloud. The color shown on the land surface depicts the instantaneous net ecosystem exchange from this simulation from the Community Climate System Model Version 3 (CCSM3). (figure produced by Jamison Daniel for the *SciDAC Review*).

**Figure 2. (below)** Cross section of tracer concentration from a high resolution ocean simulation for a plane starting near the surface in the Northern Hemisphere and cutting deeper in the Southern Hemisphere. This is a screen shot from a LANL workstation demonstrating remote visualization of high-resolution ocean data that resides at the ORNL Leadership Computing Facility where the simulation was performed.





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Climate scientists are working hard to advance the next generation of climate models. The SciDAC project “A Scalable and Extensible Earth System Model for Climate Change Science” is focused on developing an Earth System Model that includes not only the usual physical climate fields, but also the biological and chemical processes important for simulating the full carbon and sulfur cycles. These biogeochemical cycles are important for understanding the greenhouse gas and aerosol feedbacks in the climate system and how the Earth’s land and ocean ecosystems affect fluxes of carbon and sulfur between the surface and the atmosphere.

As part of this effort, it is important to evaluate current land surface carbon models and decide which model or model components should form the basis of the land formulation in the Earth System Model. A Carbon LAnd Model Intercomparison Project (C-LAMP) was initiated with the goal of evaluating several land surface models in the context of the full Community Climate System Model (CCSM). A critical part of any such intercomparison is to permit all scientists access to the simulation results for evaluation. The ESG played a critical role in distributing C-LAMP simulation data from Oak Ridge National Laboratory (ORNL) to the pool of C-LAMP scientists around the country. The analysis of those results has identified strengths and weaknesses of current models to inform decisions on which components to include in future CCSM simulations (see Fig. 1). Further simulations are being performed to evaluate other aspects of these models and identify necessary model developments for future releases.

Climate modelers are also improving their ability to project regional climate change impacts, particularly over the next several decades. This effort requires high spatial resolution, not only to provide results at finer spatial scales, but also to reduce known biases in coarse resolution models. However, the data volume generated by high resolution models requires that much of the

simulation analysis be performed in place as moving that volume of data to the scientist’s home site is not feasible. In addition, analysis of high resolution data requires parallel tools due to the memory and processing power required to compute diagnostics on these large fields.

Eddy-resolving ocean simulations provide one example of the difficulty in high resolution analysis. Researchers at Los Alamos National Laboratory (LANL) have been performing global ocean simulations at 0.1-degree horizontal resolution (~10km) and have shown that resolving the mesoscale eddies at this resolution is required to accurately reproduce many features of the ocean circulation. However, since each three dimensional ocean field from one instance in time requires 1.4 GB of memory, diagnostics with multiple fields or time averages of those fields requires substantial memory and processing power and traditional analysis tools were inadequate.

As a part of the ESG project, LANL scientists have explored the remote use of ParaView for the analysis of eddy-resolving ocean simulation data residing at ORNL. The use of ParaView has been very successful (see Fig. 2), demonstrating the ability to do parallel analysis of high resolution data as well as performing that analysis remotely and interactively. Integration of this tool into the ESG analysis interface has now begun and will enable ESG to provide parallel remote analysis capabilities to keep up with the increasing volume of data generated by climate simulations.

In both the cases described here, ESG has played an important role in directly supporting climate science within the Department of Energy and throughout the climate community.

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